**F22, August (26026) – Answers and suggested solutions**

**1)**

Angiv antallet af uparrede elektroner i svovl (S).
---
*State the number of unpaired electrons in sulfur (S).*

0
1
2*
3
4

<u>Suggested solution:</u>
The ground state electron configuration of S is $1s^22s^22p^63s^23p^2$. Only the 2 $3p^2$ electrons are unpaired (they are located in two different p orbitals due to the Pauli exclusion principle).

**2)**

Løsrivelsesarbejdet (in English: work function) for kalium (K) er 221 kJ/mol. Beregn den kinetiske energi af en elektron skubbet ud af kalium, hvis en kalium prøve bestråles med 150 nm fotoner.
---
*The work function of potassium (K) is 221 kJ/mol. Calculate the kinetic energy of the ejected electrons if photons with a wavelength of 150 nm are used to irradiate K.*

220 J
$3.7 \times 10^{-9}$ J
$1.3 \times 10^{-18}$ J
$9.6 \times 10^{-19}$ J*
$5.1 \times 10^{-20}$ J

<u>Suggested solution:</u>
We know: KE = hν - W
The work function (W) is 221 kJ/mol → $221000/6.022x10^{23} = 3.67x10^{-19}$ J/atom
The frequency of the incident photons is $\nu = c/\lambda = 3x10^8 / 150x10^{-9} = 2x10^{15}$ Hz

- ➔ KE = $9.59 \times 10^{-19}$ J

**3)**

Arrangér de følgende kemiske forbindelser efter graden af ionisk karakter i deres binding:
---
*Arrange the following compounds in order of increasing ionic character of the bond:*

HF, CaO, CuS, KF, MgO.

CaO < CuS < HF < KF < MgO
CuS < HF < MgO < CaO < KF*
CuS < MgO < CaO < KF < HF
HF < MgO < KF < CaO < CuS
KF < CaO < MgO < CuS < HF

Suggested solution:
The differences in electronegativities are:
HF: 1.9
CaO: 2.5
CuS: 0.6
KF: 3.2
MgO: 2.3
The ionic character increases with the electronegativity difference.

**4)**

Hvilke af disse molekyler er polære (dvs. har et permanent dipolmoment)?
---
*Which of these molecules are polar (i.e. have a permanent dipole moment)?*

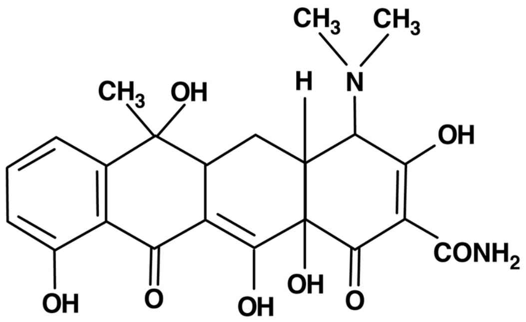
$PCl_3$, $PCl_5$, $CF_2Br_2$, $CO_2$, HCN

$PCl_3$: non-polar / $PCl_5$ non-polar / $CF_2Br_2$ non-polar / $CO_2$ non-polar / HCN polar
$PCl_3$: polar / $PCl_5$ polar / $CF_2Br_2$ polar / $CO_2$ non-polar / HCN non-polar
$PCl_3$: non-polar / $PCl_5$ polar / $CF_2Br_2$ non-polar / $CO_2$ polar / HCN non-polar
$PCl_3$: non-polar / $PCl_5$ non-polar / $CF_2Br_2$ polar / $CO_2$ non-polar / HCN polar
$PCl_3$: polar / $PCl_5$ non-polar / $CF_2Br_2$ polar / $CO_2$ non-polar / HCN polar*

Suggested solution:
$PCl_3$ is non planar molecule due to the presence of a lone pair on the P atom (similar to $NH_3$ in the book) and is polar.
$PCl_5$ has a trigonal bipyramidal structure (as shown in figure 10.4) and is thus non-polar.
$CF_2Br_2$ has a tetrahedral structure similar to that of $CH_2Cl_2$ (example 10.2 in the book) and is therefore polar.
$CO_2$ is a linear, symmetrical molecule, which is therefore non-polar.
HCN is a linear, non-symmetrical molecule, with C located between two different atoms having different electronegativities. As a consequence, HCN is polar.

**5)**

Identificer det svar, hvor alle tre funktionelle grupper indgår i den viste struktur:
---
*Identify the answer, where all three functional groups are present in the following molecule:*

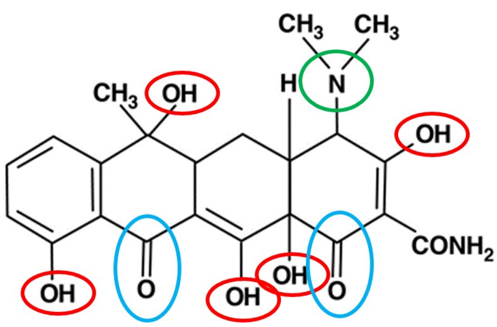



Hydroxyl / Keton / Amin*
Hydroxyl / Carboxyl / Amin
Ester / Keton / Amin
Hydroxyl / Carboxyl / Æter
Aldehyd / Keton / Ester

*Hydroxyl / Ketone / Amine**
*Hydroxyl / Carboxyl / Amine*
*Ester / Ketone / Amine*
*Hydroxyl / Carboxyl / Ether*
*Aldehyde / Ketone / Ester*

Suggested solution:
Hydroxyl / Keton / Amin

*Hydroxyl / Ketone / Amine*




**6)**

60.5 g kloroform ($CHCl_3$, ikke-elektrolyt) opløses i 1 L carbon tetraklorid ($CCl_4$), som har en massefylde på 1.59 g/cm$^3$. Som resultat er frysepunktet af $CCl_4$ nu 10 $^oC$ lavere end for ren $CCl_4$. Hvad er $K_f$ konstanten for $CCl_4$?

---

*60.5 g of chloroform ($CHCl_3$, a non-electrolyte) are dissolved in 1 L of carbon tetrachloride ($CCl_4$), which has a density of 1.59 g/cm$^3$. This results in a 10 $^oC$ lowering of the freezing point of $CCl_4$. What is the $K_f$ constant of $CCl_4$?*

-31.4 $^oC/m$
-19.7 $^oC/m$
4.7 $^oC/m$
19.7 $^oC/m$
31.4 $^oC/m$*

Suggested solution:
$\Delta T_f = i\, K_f\, m$ with i = 1 (non-electrolyte) → $K_f = \Delta T_f / m$
Chloroform has a molar mass of 119.4 g/mol → 60.5 g / 119.4 g/mol = 0.506 mol chloroform
We have 1 L $CCl_4$ with a density of 1.59 g/cm$^3$, hence 1.59 kg.
m = 0.506 mol / 1.59 kg = 0.318 mol/kg

$K_f = \Delta T_f / m = 10\ ^oC / 0.318\ mol/kg = 31.4\ ^oC/m$

**7)**

Nikkel (Ni) krystalliserer i en kubisk tæt-pakket struktur (fcc, face-centered cubic). Siden af enhedscellen er a = 352.4 pm. Beregn nikkels massefylde.
---
*Nickel (Ni) crystallizes in a cubic close-packed structure (fcc, face centered cubic) with unit cell edge length a = 352.4 pm. Calculate the density of Ni.*

17.8 $g/cm^3$
8.9 $g/cm^3$*
4.5 $g/cm^3$
2.2 $g/cm^3$
0.7 $g/cm^3$

Suggested solution:
See example 12.3 in the book:
For a cubic close-packed structure, there are 4 Ni atoms per unit cell.
The mass of one unit cell is $m = 4\ (58.71 / 6.022 \times 10^{23}) = 3.9 \times 10^{-22}$ g/unit cell
$V = a^3 = 4.38 \times 10^{-23}\ cm^3$
$V = m/d \rightarrow d = m/V = 8.9\ g/cm^3$

**8)**

Mængden af en organisk forbindelse halveres hvert minut. Hvad er hastighedskonstanten for nedbrydningen af denne forbindelse?
---
*The amount of an organic compound is divided by 2 every minute. What is the rate constant for the decomposition of this compound?*

≈0.5 $s^{-1}$
≈0.347 $s^{-1}$
≈0.0115 $s^{-1}$*
≈0.0167 $s^{-1}$
≈0.0333 $s^{-1}$

Suggested solution:
See section 14.3, figure 14.9 and equation 14.5 in the book:
$t_{1/2} = 0.693/k \rightarrow k = 0.693/t_{1/2} = 0.693/60 = 0.0115\ s^{-1}$

**9)**

Hvad er ligevægtskonstanten ($K_p$) for den kemiske reaktion: $2A(g) + B(g) \leftrightharpoons 3C(g) + D(g)$, hvis partialtrykkene ved ligevægt er hhv. [A] = 0.4 atm, [B] = 0.25 atm, [C] = 0.5 atm og [D] = 0.2 atm.
---

*Which equilibrium constant $K_p$ corresponds to the reaction $2A(g) + B(g) \leftrightharpoons 3C(g) + D(g)$ if the partial pressures at equilibrium are [A] = 0.4 atm, [B] = 0.25 atm, [C] = 0.5 atm and [D] = 0.2 atm?*

$K_p = 1.6$
$K_p = 1.08$
$K_p = 1$
$K_p = 0.625$*
$K_p = 0.01$

Suggested solution:

$$\frac{[C]^3 \cdot [D]}{[A]^2 \cdot [B]} = \frac{0.5^3 \cdot 0.2}{0.4^2 \cdot 0.25} = 0.625$$

**10)**

Platin (Pt, densitet 21.43 g/cm$^3$) bruges som katalysator i mange kemiske processer, hvor det er tilstede som nanopartikler for at maksimere forholdet mellem overfladeareal og volumen. Hvor mange platinatomer findes der i en kugleformet platinpartikel med en diameter på 5 nm (dvs. 2.5 nm radius)?
---
*Platinum (density 21.43 g/cm$^3$) is used as catalyst in many chemical conversion processes in the form of nanoparticles to maximize the surface area to volume ratio. How many platinum atoms can be found in one spherical platinum particle with a diameter of 5 nm (i.e. 2.5 nm radius)?*

ca. 35
ca. 4330*
ca. 14000
ca. $3.6 \times 10^5$
ca. $8.1 \times 10^{14}$

Suggested solution:
Volume of one particle:

$\frac{4}{3}\pi(2.5 \times 10^{-9})^3\ m^3 = \frac{4}{3}\pi(2.5 \times 10^{-7})^3\ cm^3 = 6.545 \times 10^{-20}$ cm$^3$

m(Pt) = 21.43 g/cm$^3$ × $6.545 \times 10^{-20}$ cm$^3$ = $1.4026 \times 10^{-18}$ g

n(Pt) = ($1.4026 \times 10^{-18}$ g) / (195.1 g/mol) = $7.189 \times 10^{-21}$ mol

1 mol Pt = $6.022 \times 10^{23}$ Pt atoms

Number of atoms:

$7.189 \times 10^{-21}$ mol × ($6.022 \times 10^{23}$ / mol) = 4329

**11)**

Du skal fremstille 25 mL vandig opløsning af KOH med en koncentration på 50 mM. Dette gøres ved at fortynde et givet volumen af en 1250 mM KOH opløsning med vand til et totalt volumen på 25 mL. Hvilket volumen af 1250 mM KOH opløsningen skal du bruge?

---

*You need to prepare 25 mL aqueous KOH with a concentration of 50 mM by diluting a given volume of a 1250 mM KOH with water to a total volume of 25 mL. What is the volume of the stock solution that should be used?*

0.010 mL
0.025 mL
0.1 mL
0.5 mL
1.0 mL *

Suggested solution:

$C_1V_1 = C_2V_2$

$V_1 = C_2V_2/C_1 = (0.050 \text{ mol/L} \times 0.025 \text{ L}) / (1.250 \text{ mol / L}) = 1 \text{ mL}$

**12)**

En brændselscelle bruger 587 L $H_2$ pr. minut (ved 25 °C, 1 atm), ifølge reaktionen:

$2H_2 + O_2 \rightarrow 2H_2O$

Hvad er den mindste luftstrøm, som kræves for at opretholde en fuldstændig konvertering af $H_2$ til $H_2O$ ved 25 °C, 1 atm? Antag 100% konvertering til $H_2O$, et partialtryk af $O_2$ på 0.2 atm. og at gasserne kan beskrives som idealgasser.

---

*A fuel cell system consumes 587 L $H_2$ per minute (25 °C, 1 atm), according to the reaction below.*

*$2H_2 + O_2 \rightarrow 2H_2O$*

*What is the minimum air flow needed (25 °C, 1 atm) for complete conversion of $H_2$ to $H_2O$ (i.e. 100% yield of $H_2O$), assuming that the $O_2$ partial pressure in air is 0.2 atm and that the gasses can be described as ideal gasses?*

294 L/min (correct stoichiometry, pure oxygen)
587 L/min (wrong stoichiometry, pure oxygen)
1164 L/min (wrong stoichiometry, pure oxygen)
1468 L/min*
5870 L/min (wrong stoichiometry, air)

Suggested solution:
Hydrogen flow: 587 L/min
Minimum $O_2$ flow: 293.5 L/min

Dalton´s law of partial pressures:

$p(O_2)$ =0.2 atm → 20 vol.% $O_2$

Minimum air flow = 5 × 293.5 L/min = 1467.5 L air per minute

**13)**

I løbet af 30 millisekunder efter en kollision vil en airbag i en personbil være fuldt oppustet med nitrogen ($N_2$), som dannes ved følgende reaktion:

$2NaN_3$ (s) → 2Na (s) + $3N_2$ (g)

Hvor mange gram $NaN_3$ skal bruges for at generere 70 L $N_2$ (antag standard temperatur og tryk)?
---
*Within 30 milliseconds after collision detection, airbags installed in passenger cars are fully inflated by nitrogen ($N_2$) that is released by the following decomposition reaction:*

*$2NaN_3$ (s) → 2Na (s) + $3N_2$ (g)*

*How many grams of $NaN_3$ is needed to generate 70 L of $N_2$ at standard temperature and pressure?*

Answer options:
68 g (wrong mol ratio)
186 g (right mol ratio but 25 C instead of 0 C)
135 g *
203 g (wrong mol ratio)
304 g (wrong mol ratio)

Suggested solution:

pV = nRT

$n(N_2)$ = pV /RT = (1 atm × 70 L) / (0.0821 L × atm. $K^{-1}$ $mol^{-1}$ × 273.15 K)

$n(N_2)$ = 3.1214 mol

$n(N_2)$ : $n(NaN_3)$ = 3:2
$n(NaN_3)$ = 2.081 mol

$m(NaN_3)$ = 2.081 mol × 65.01 g/mol = 135 g

**14)**

Toluen (methylbenzen) er en af bestanddelene i benzin og forbrændes ifølge nedenstående reaktionsligning. Angiv den varmeenergi, som udvikles når 1 L toluen ($C_7H_8$, densitet 0.87 g/mL) forbrændes fuldstændig ved standardbetingelser.

---

*Toluene (methylbenzene) is one of the components of gasoline and combusts according to the reaction below. What is the amount of heat evolved when 1 L of toluene ($C_7H_8$, density 0.87 g/mL) is combusted under standard conditions?*

$a$ $C_7H_8$ (l) + $b$ $O_2$ (g) → $c$ $CO_2$ (g) + $d$ $H_2O$ (l)

| | $C_7H_8$ (g) | $O_2$ (g) | $CO_2$ (g) | $H_2O$ (l) |
|---|---|---|---|---|
| $\Delta H_f^0$ (kJ/mol) | 50 | 0 | -394 | -286 |

$C_7H_8$ (l) → $C_7H_8$ (g) $\Delta H_{vap}$ = 38 kJ/mol

Answer options:

-1.49 × $10^3$ kJ (not balanced reaction)
-3.95 × $10^3$ kJ (for one mole…)
-37.0 × $10^3$ kJ*
-37.4 × $10^3$ kJ (not considering evaporation enthalpy of toluene)
-37.7 × $10^3$ kJ (subtracting evaporation enthalpy instead of adding)

Suggested solution:

**1**$C_7H_8$ (l) + **9**$O_2$ (g) → **7**$CO_2$ (g) + **4**$H_2O$ (l)

$\Delta H = \Sigma n \Delta H_f^0$ (products) - $\Sigma m \Delta H_f^0$ (reactants)

Strategy: According to Hess law the enthalpy change of the reaction will equal the sum of the enthalpy changes of the steps)

Step 1:
$C_7H_8$ (l) → $C_7H_8$ (g) $\Delta H_{vap}$ = 38 kJ/mol

Step 2:
$C_7H_8$ (g) + 9$O_2$ (g) → 7$CO_2$ (g) + 4$H_2O$ (l) $\Delta H^0$ = ((7 × (-394 kJ/mol)) + (4 × (-286 kJ/mol))) – ((1 × (50 kJ/mol) + (9 × (0 kJ/mol))) = -3726 kJ/mol – 50 kJ/mol = -3952 kJ/mol

Sum:
$C_7H_8$ (l) + 9$O_2$ (g) → 7$CO_2$ (g) + 4$H_2O$ (l) $\Delta H$ = -3952 kJ/mol + 38 kJ/mol = -3914 kJ/mol

Amount of toluene:
n($C_7H_8$) = 870 g / 92.1 g/mol = 9.45 mol

Heat evolved = 9.45 mol × -3914 kJ/mol = -36987 kJ

**15)**

Beregn ligevægtskonstanten for nedenstående redoxreaktion ved standardbetingelser:
---
*What is the equilibrium constant for the following redox reaction under standard conditions?*

$Fe^{2+}$ (aq) + Cd (s) ⇄ Fe (s) + $Cd^{2+}$ (aq)

$Fe^{2+}$ (aq) + $2e^-$ → Fe (s) $E^0$ = -0.44 V
$Cd^{2+}$ (aq) + $2e^-$ → Cd (s) $E^0$ = -0.40 V

$4.07 \times 10^{-29}$ ($E^0_{cell}$ = -0.84 V)
$7.71 \times 10^{-4}$(log instead of ln)
$4.45 \times 10^{-2}$ *
0.21 (n =1)
22.5 ($E^0_{cell}$ = -0.04 V)

Suggested solution:

$E^0_{cell} = E^0_{red} - E^0_{ox}$ = -0.44 V – (-0.40 V) = -0.04 V

$E^0_{cell}$ = (0.0257 V / $n$) × ln $K$ $n = 2$

ln $K$ = ($n \times E^0_{cell}$) / 0.0257 V = -3.113

$K$ = 0.0445

**16)**

p$K_a$ for myresyre (methansyre, HCOOH) er 3.75. Hvad er pH i en vandig opløsning af myresyre med koncentration 100 mM?
---
*The p$K_a$ for formic acid (HCOOH) in water is 3.75. What is the pH of an aqueous solution of formic acid with a concentration of 100 mM?*

0.9
1.5
1.8
2.0
2.4 *

Suggested solution:

$$HCOOH\ (aq.) + H_2O\ (l) \rightleftarrows HCOO^-\ (aq.) + H_3O^+\ (aq.)$$

| | | | |
|---|---|---|---|
| Initial conc. | 0.100 | 0 | 0 |
| Change | -x | +x | +x |
| Eq. | 0.100-x | x | x |

$pK_a = 3.75$

$K_a = 1.78 \times 10^{-4}$

$K_a = [HCOO^-][H_3O^+] / [HCOOH]$

Assume x<<0.100 and:

$1.78 \times 10^{-4} = x^2 / (0.100-x) = x^2 / 0.100$

$x^2 = 0.100 \times 1.78 \times 10^{-4}$

x = 0.0042 or -0.0042 (physically impossible)

Test approximation:

0.0042 M / 0.100 M = 4.2% (approx. ok)

At equilibrium:

$[H_3O^+] = 0.0042$ M

pH = -log 0.0042 = 2.38

**17)**

Opløseligheden af kaliumkarbonat ($K_2CO_3$) i vand ved 20 °C er 1103 g/L. Hvad er opløselighedsproduktet ($K_{sp}$) for $K_2CO_3$ i vand ved 20 °C?
---
*The solubility of potassium carbonate ($K_2CO_3$) in water at 20 °C is 1103 g/L. What is the solubility product ($K_{sp}$) for $K_2CO_3$ in water at 20 °C?*

64 $M^2$
64 $M^3$
508 $M^3$
2033 $M^3$ *
4055 $M^4$

Suggested solution:

$K_2CO_3$ (s) ⇄ $2K^+$ (aq.) + $CO_3^{2-}$ (aq.)

$n(K_2CO_3) = (1103\ g) / (138.205\ g/mol) = 7.98\ mol$

$[K^+] = 15.96\ M$
$[CO_3^{2-}] = 7.98\ M$

$K_{sp} = [K^+]^2 [HCO_3^-]\ M^3 = 2033\ M^3$

**18)**

Angiv de støkiometriske koefficienter (a-f), som afstemmer redoxreaktionen nedenfor i en vandig, sur opløsning.
---
*Indicate which set of stoichiometric coefficients (a-f) that balances the redox reaction below in aqueous acidic environment:*

$a\ Fe^{2+} + b\ Cr_2O_7^{2-} + c\ H^+ \rightarrow d\ Fe^{3+} + e\ Cr^{3+} + f\ H_2O$

$a = 6, b = 1, c = 14, d = 6, e = 2, f = 7$ *
$a = 3, b = 1, c = 6, d = 3, e = 2, f = 3$
$a = 6, b = 1, c = 16, d = 6, e = 2, f = 8$
$a = 10, b = 2, c = 28, d = 10, e = 4, f = 14$
$a = 3, b = 1, c = 12, d = 3, e = 2, f = 6$

Suggested solution:

$\boldsymbol{6}\ Fe^{2+} + \boldsymbol{1}\ Cr_2O_7^{2-} + \boldsymbol{14}\ H^+ \rightarrow \boldsymbol{6}\ Fe^{3+} + \boldsymbol{2}\ Cr^{3+} + \boldsymbol{7}\ H_2O$

**19)**

Angiv antallet af uparrede elektroner i henholdsvis $[FeCl_6]^{4-}$ og $[Co(CN)_6]^{4-}$ kompleks-ioner, begge med oktaederisk symmetri.
---
*Find the number of un-paired electrons in $[FeCl_6]^{4-}$ and $[Co(CN)_6]^{4-}$, respectively, both with octahedral symmetry.*

4, 1*
0, 3
1, 1
5, 1
1, 4

Suggested solution:

$[FeCl_6]^{4-}$
Fe(II) electron configuration [Ar] $3d^6$
$Cl^-$ weak field ligand

| | |
|---|---|
| ↑ | ↑ |

| | | |
|---|---|---|
| ↑↓ | ↑ | ↑ |

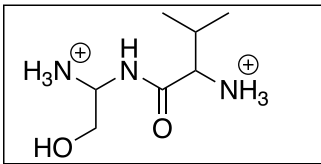
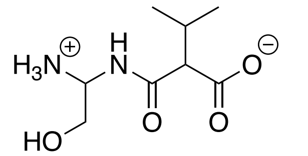
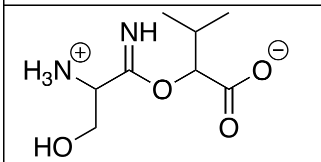
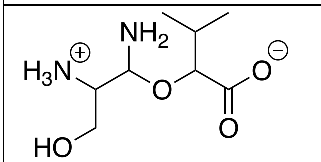
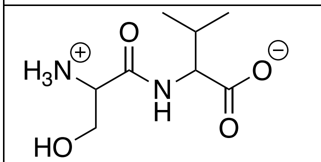
$[Co(CN)_6]^{4-}$
Co(II) electron configuration [Ar] $3d^7$
$CN^-$ strong field ligand

| | |
|---|---|
| ↑ | |

| | | |
|---|---|---|
| ↑↓ | ↑↓ | ↑↓ |

**20)**

Hvilken kemisk struktur svarer til det dipeptid, der kan dannes af aminosyrerne serin og valin?
---
*Which chemical structure corresponds to the dipeptide that can be formed from the amino acids serine and valine?*

| | |
|---|---|
|  | |
|  | |
|  | |
|  | |
|  | * |